Focus topics for the ECFA study on Higgs / Top / EW factories

Report from the Focus Groups: ZHang and LUMI experts' groups

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A detector for a Higgs factory and beyond: ILD

Outline

Abstract

In order to stimulate new engagement and trigger some concrete studies in areas where further work would be beneficial towards fully understanding the physics potential of a Higgs / Top / Electroweak factory, we propose to define a set of focus topics. The general reasoning and the proposed topics are described in this document.

1. The paper on focus topics for the ECFA study on Higgs / Top / EW factories has been released

(https://cernbox.cern.ch/pdf-viewer/public/D68ojcg6OjMx2K4/ECFA_Focus_Topics.pdf)

2. I'll summarize here the ILD results associated with the focus topics ***Zh angular distributions and CP studies*** (**ZHang**) and the ***Precision luminosity measurement*** (**LUMI**)

3. And also highlight possible work to be done by the ILD

Zh angular distributions and CP studies (ZHang)

Expert Team: Cheng Li, Chris Hays, Gudrid Moortgat-Pick, Ivanka Bozovic, Ken Mimasu, Markus Klute, Sandra Kortner

- **CP-even interactions**: Could ZH angular observables help to increase precision of λ in ZH? (leave to Junping to report in more details)
- **CP-odd interactions**: Can be probed by reconstructing the Higgs and Z boson production/decay planes (i.e. HZZ in ZZ-fusion at 1 TeV ILC [1]), or by measuring and utilizing the polarizations of the Higgs-boson decay particles (i.e. H to $\tau\tau$ decay at 250 GeV ILC[2])

These CP-odd interactions could provide an ingredient to explain the observed matter-antimatter asymmetry in the universe. Prior analyses of ZH production have found good sensitivity to CP-odd interactions, and a further understanding of this sensitivity is a primary goal of this topic.

Zhang – previous(ongoing) ILC/ILD work

(68% CL, pure scalar)

[Snowmass White Paper: CPV, arXiv:2205.07715v3]

Collider	pp	pp	pp	e^+e^-	e^+e^-	e^+e^-	e^+e^-	e^-p	$\gamma\gamma$	$\mu^+\mu^-$	$\mu^+\mu^-$	target
E (GeV)	14,000	14,000	10 tmes more $\mathcal{L}$	250	350	500	1 TeV VBF 8 ab^{-1}	1,300	125	125	3,000	(theory)
$\mathcal{L}$ (fb^{-1})	300	3,000		250	350	500		1,000	250	20	1,000	
HZZ/HWW	$4.0\cdot10^{-5}$	$2.5\cdot10^{-6}$	✓	$3.9\cdot10^{-5}$	$2.9\cdot10^{-5}$	$1.3\cdot10^{-5}$	$1.6\cdot10^{-5}$	✓	✓	✓	✓	$< 10^{-5}$
$H\gamma\gamma$	–	0.50	✓	–	–	–	–	–	0.06	–	–	$< 10^{-2}$
$HZ\gamma$	–	~ 1	✓	–	–	–	~ 1	–	–	–	–	$< 10^{-2}$
Hgg	0.12	0.011	✓	–	–	–	–	–	–	–	–	$< 10^{-2}$
$Ht\bar{t}$	0.24	0.05	✓	–	–	0.29	0.08	✓	–	–	✓	$< 10^{-2}$
$H\tau\tau$	0.07	0.008	✓	0.01	0.01	0.02	0.06	–	✓	✓	✓	$< 10^{-2}$
$H\mu\mu$	–	–	–	–	–	–	–	–	–	✓	–	$< 10^{-2}$

1. I. Bozovic, N. Vukasinovic, G. Kacarevic, Probing CPV mixing in the Higgs sector in VBF at 1 TeV ILC, PoS(EPS-HEP2023)404, *to be submitted to Phys. Rev. D*
2. D. Jeans and G. W. Wilson, Measuring the CP state of tau lepton pairs from Higgs decay at the ILC, Phys. Rev. 302 D 98 013007 (2018), arXiv:1804.01241
3. Working Group Report: Higgs Boson", in Community Summer Study 2013: Snowmass on the Mississippi. 10, 2013, arXiv:1310.8361

Zhang – potential ILC/ILD studies

Further studies can determine whether there is scope to improve the sensitivity, or to extend it to additional interactions.

PHYSICS ANALYSES

- Other channels in HZ: (inclusive Z decays), H to WW to hadrons (decay)
- Other energies: H to $\tau\tau$ at higher ILC energies
- Analyses refinement: use optimal observable(s) to enhance sensitivity to the Higgs CP structure

THEORY

- Expand interpretation framework connecting SMEFT/angular observables/specific BSM models (to understand the baryon asymmetry)

ALGORITHMS

- Tracking and ID: τ and jet reconstruction
- Jet charge measurement (quark-antiquark separation in H to VV hadronic decays)

Precision luminosity measurement (LUMI)

Expert Team: Ivanka Bozovic, Mogens Dam, Fulvio Piccinini, Wiesław Płaczek, André Sailer, Maciej Skrzypek, Graham Wilson; Paolo Azzuri, Ayres Freitas, Adrián Irles, Andreas B. Meyer

- **Low-angle Bhabha scattering** (LABS): Requires dedicated detector at ϑ<100 mrad; Challenging systematics should be quantified in a full detector simulation including backgrounds in the very forward region. This calls for novel and revised studies (at linear colliders), in line with the evolving design of the MDI region
- **Di-photon production**: Avoids some of the challenges of LABS, in particular the severe metrology requirements and the significant impact of the hadronic vacuum polarization; Central measurement ($|\cos\vartheta|$ <0.9)

Precision of the integrated luminosity is important for all cross-section and line-shape measurements, in particular the Z-pole, so it is crucial to reduce the uncertainty to the one comparable to LEP ($3.4 \cdot 10^{-4}$).

LABS – previous(ongoing) ILC/ILD work

	LEP [131]	FCC-ee (Z pole)	ILC [133], [134] ($\sqrt{s} > 250$ GeV)
LumiCal distance from IP [m]	2.5	1.1	2.48
Precision target	3.4×10^{-4}	10^{-4}	10^{-3}
Tolerance for			
inner radius [μm]	4.4	$\mathcal{O}(1)$	4
outer radius [μm]	?	$\lesssim 3$	?
distance between two LumiCals [μm]	$\mathcal{O}(100)$	< 100	200

- (133) A. Stahl, Luminosity measurement via Bhabha scattering: Precision requirements for the luminosity calorimeter, LCDET2005004, Apr 2005 (2005). – a dedicated study on metrology at ILC energies needed
- H. Abramowicz, Forward instrumentation for ILC detectors, Journal of Instrumentation 5 (2010) P12002 (physics background, detector design and performance), arXiv:1009.2433
- I. Bozovic Jelisavcic et al., Luminosity measurement at ILC, JINST 8 (2013) P08012, arXiv:1304.4082 (correction of the beam-induced effects)

LUMI – potential ILC/ILD studies

LABS is preferred for the point-to-point lumi control, novel (central) processes to be investigated. Detailed designs for LumiCal detectors are needed for different collider setups and different detector concepts.

SIMULATION STUDIES

- ILD needs detailed metrology study for LABS at all ILC energies
- Di-photon production - A detailed study of the luminosity calibration using this process is still lacking and would be very important; Feasibility of angular acceptance precision (50 μm) for centrally reconstructed photons
- Other processes (i.e. di-muon production); Angular acceptance and position resolution of the central tracker

THEORY

- Implementation of radiative fermion pair production in LABS (di-photon) generators
- Implementation of NNLO EW corrections for di-photon production

Focus Topics/ZHang

- ✓ gitlab wiki: https://gitlab.in2p3.fr/ecfa-study/ECFA-HiggsTopEW-Factories/-/wikis/
- ✓ sign up for e-group: http://simba3.web.cern.ch/simba3/
- ✓ email the conveners of ECFA WG1 HTE group: mailto:ecfa-whf-wg1-hte-conveners@cern.ch

Focus Topics/LUMI

- ✓ gitlab wiki: https://gitlab.in2p3.fr/ecfa-study/ECFA-HiggsTopEW-Factories/-/wikis/FocusTopics/LUMI
- ✓ sign up for e-group: http://simba3.web.cern.ch/simba3/SelfSubscription.aspx?groupName=ecfa-whf-ft-lumi
- ✓ email the conveners of ECFA WG1 PRECision group: mailto:ecfa-whf-wg1-prec-conveners@cern.ch